(12)

AD A 124570

ALPHATECH INC.

3 NEW ENGLAND EXECUTIVE PARK
BURLINGTON, MA 01803
617-273-3388

83 02 017 020

ALPHATECH, INC.

12

TR-151

TOWARD A UNIFIED APPROACH TO COMBAT SYSTEM ANALYSIS

Contract Number N00014-81-C-0740

January 1983

Submitted to:

Mr. Robert Harrison
Naval Surface Weapons Center
Dahlgren, Virginia 22448

Work Unit Number

NR 460-001

Sponsored by:

Engineering Psychology Programs
Office of Naval Research
Arlington, Virginia 22217

Prepared by:

J.G. Wohl
E.E. Entin
M.G. Alexandridis
J.S. Eterno

ALPHATECH, Inc.
3 New England Executive Park
Burlington, Massachusetts 01803
(617) 273-3388

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: TR-151
2. GOVT ACCESSION NO: AD-A124570
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Toward a Unified Approach to Combat System Analysis
5. TYPE OF REPORT & PERIOD COVERED: Technical Report 8/82 - 1/83
6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): Joseph G. Wohl, Elliot E. Entin, Mark G. Alexandridis, John S. Eterno

8. CONTRACT OR GRANT NUMBER(s): N00014-81-C-0740

9. PERFORMING ORGANIZATION NAME AND ADDRESS: ALPHATECH, Inc. 3 New England Executive Park Burlington, MA 01803

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NR 460-001
11. CONTROLLING OFFICE NAME AND ADDRESS: Office of Naval Research 800 North Quincy Street Arlington, VA 22217
12. REPORT DATE: January 1983
13. NUMBER OF PAGES:
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Naval Surface Weapons Center Code N51, Combat Systems Department Dahlgren, VA 22448
15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

System decomposition, decisionmaking, systems analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two obstacles to modeling large-scale man-machine systems are addressed. They are system decomposition and human decision modeling. An existing decomposition method, IDEF, is discussed and recommendations for supplementing the method are suggested. Extant approaches to human decision modeling are briefly reviewed. The SHOR paradigm of tactical decisionmaking is presented and an example of how to use the SHOR framework for structuring the decisionmaking activity of an antisubmarine warfare commander is given.

TABLE OF CONTENTS

Page

List of Figures iii

List of Tables iii

1. Introduction and Summary 1

2. Decomposition for Combat System Analysis 3

2.1 Introduction. 3
2.2 Perspectives. 4
2.3 System decomposition with $IDEF_O$ 5
2.4 Recommended additions to $IDEF_O$. 9

2.4.1 Queuing. 9
2.4.2 Data storage 10
2.4.3 Human decisionmaking 11

2.5 Measuring system effectiveness. 12
2.6 Discussion. 13

3. Modeling Human Cognitive Decisionmaking. 14

3.1 Artificial intelligence 14
3.2 Cognitive simulation. 17
3.3 The SHOR paradigm 19
3.4 SHOR and combat system analysis 21

4. Concluding Remarks 24

References 25

List of Figures

Number		Page
2-1	Hierarchical Structure of $IDEF_0$ Diagrams.	6
2-2	$IDEF_0$ Activity Box.	7
2-3	Tactical Air Control System: Highest Level $IDEF_0$ Diagram . . .	7
2-4	Tactical Air Control System: Second Level $IDEF_0$ Diagram. . . .	8
2-5	Second Level $IDEF_0$ Diagram with Data Storage.	11
3-1	Antisubmarine Warfare Threat Activity Diagram	22
3-2	SHOR Decomposition of Antisubmarine Warfare Threat Activity . .	22

List of Tables

Number		Page
3-1	SHOR Paradigm in Terms of Task Elements	21

SECTION 1

INTRODUCTION AND SUMMARY

The need for a unified approach to combat system analysis derives from the following two facts. First, future command, control, and communication (C^3) systems will emphasize distributed decisionmaking systems which are necessarily more complex than existing centralized systems. Distributed systems increase system survivability and reaction time, but require more organization and planning than the traditional, centralized C^3 systems [1]. Second, military personnel training has not kept pace with technological innovation, hence the addition of new weapons systems, sensors, and electronic technology has not brought about as significant an improvement in system performance as was portended. For example, a proposed addition to a C^3 system might be a new central processing unit (CPU) for a data processor that is twice as fast as the existing CPU. At a glance, the innovation appears to be overwhelmingly beneficial. It is, however, oftentimes the case that such an innovation may affect total system performance marginally. If the system, its components, and their interactions were known an analyst could determine the reason for this counterintuitive result, e.g., the additional data were inconsequential or the military personnel were unable to attend to the extra information. A unified approach to combat system analysis would enable the military to quantify such changes in the system hardware, software, personnel, and policy.

Many technical obstacles must be overcome before a recipe for combat system analysis is available. Herein, two are addressed. They are large-scale system decomposition and modeling human decisionmaking.

Section 2 presents an available technique for large-scale decomposition, suggests modifications to encode requirements specific to combat systems, and alludes to a method whereby the static decomposition information can be used as input to a dynamic simulation so that performance can be quantified. Two approaches to human cognitive decisionmaking modeling are briefly reviewed, and a paradigm for such modeling is presented in Section 3. Section 4 summarizes the report.

SECTION 2

DECOMPOSITION FOR COMBAT SYSTEM ANALYSIS

2.1 INTRODUCTION

Analysis of complex, large-scale systems such as command and control (C^2) or combat systems has been hindered by the lack of an adequate means of representing the physical, functional, and organizational aspects of such systems in a single, unifying perspective.

The need for a unified method of representing these three aspects of complex systems arises from two requirements. They are:

1. A common basis for communication among operational personnel, tactitians, and systems analysts.
2. An operational basis for engineering analysis.

Hitherto, engineering analysis has been successful at the subsystem level to the extent that system requirements could be decomposed into subsystem requirements and, subsequently, into subsystem specifications. Decomposition and definition of requirements is a fairly mundane task for well-structured, well-partitioned systems; especially, those with centralized command and hierarchical structure. New systems, however, emphasize survivability through distributed processing and control. It is these systems that are of primary interest.

Traditional system functional block diagrams and specification family trees, while appropriate for equipment and well-partitioned system description, cannot readily be employed to represent the human, organizational, and

procedural aspects of an adaptive, multimode, multinode system in which human decisionmaking is a critical activity. One technique is evolving to analyze such complex systems. It is called $IDEF_0$ [2]. It is by no means a recipe for systems analysis, but is useful for large-scale system decomposition. The objective, then, of this section is to:

1. Describe briefly the technique as it exists today.
2. Recommend modifications to more adequately meets the needs of (C^3) and combat systems analysts.
3. Indicate how the methodology could be employed to measure the performance and effectiveness of C^3 and combat systems.

2.2 PERSPECTIVES

Systems analyses can be performed from three perspectives.

Systems perspective. This perspective provides a description of system and subsystem capabilities, interrelationships, interfaces, and data flows. Analyses undertaken from a systems perspective address questions about what constitutes the system.

Functional perspective. This perspective describes the functions, processes, procedures, and structured decisions. It also describes the flow of information between functions. Analyses undertaken from a functional perspective address questions about how the system operates.

Organizational perspective. This perspective portrays geographic and hierarchical distribution of authority, responsibility, and flow of control. It also associates functions and processes, and systems and subsystems, with organizational levels and decisionmakers. Analyses undertaken from this perspective address questions about how the system is organized.

2.3 SYSTEM DECOMPOSITION WITH $IDEF_0$

IDEF is an acronym for the Integrated Computer-Aided Manufacturing DEFinition $Language_0$* [2]. $IDEF_0$ is used to describe the relationships between functions and data within a system in a manner that facilitates understanding of the system.

The basic unit of representation is the $IDEF_0$ model, consisting of a set of related diagrams that are organized in a hierarchical manner as shown in Fig. 2-1. Two submodels comprise the total $IDEF_0$ model. They are the system activity models and the system data models. The former models provide a detailed descriptions of the functions, processes, and decisions, whereas the latter display structured breakdowns of the data.

Generically, an activity block is depicted in Fig. 2-2. The input data, the location of the activity or effector of the activity, and the controls are the function, or activity inputs, and there is one output. The controls are comprised of some, or all, of the following: activity objectives, directives, constraints, doctrine and policy. The $IDEF_0$ technique is most easily conveyed through an illustrative example.

An example of $IDEF_0$ decomposition. Figures 2-3 and 2-4 are the activity models for the first and second levels of the U.S. Air Force's primary tactical command, control, communication and intelligence (C^3I) system -the Tactical Air Control System (TACS). In Fig. 2-3, the inputs are tactical event data, the resource or activity effector is the tactical air control system, and the controls are the Air Force policy and doctrine. The activity is to

*Two other versions of the IDEF method exist. They were devised primarily for the analysis of manufacturing systems.

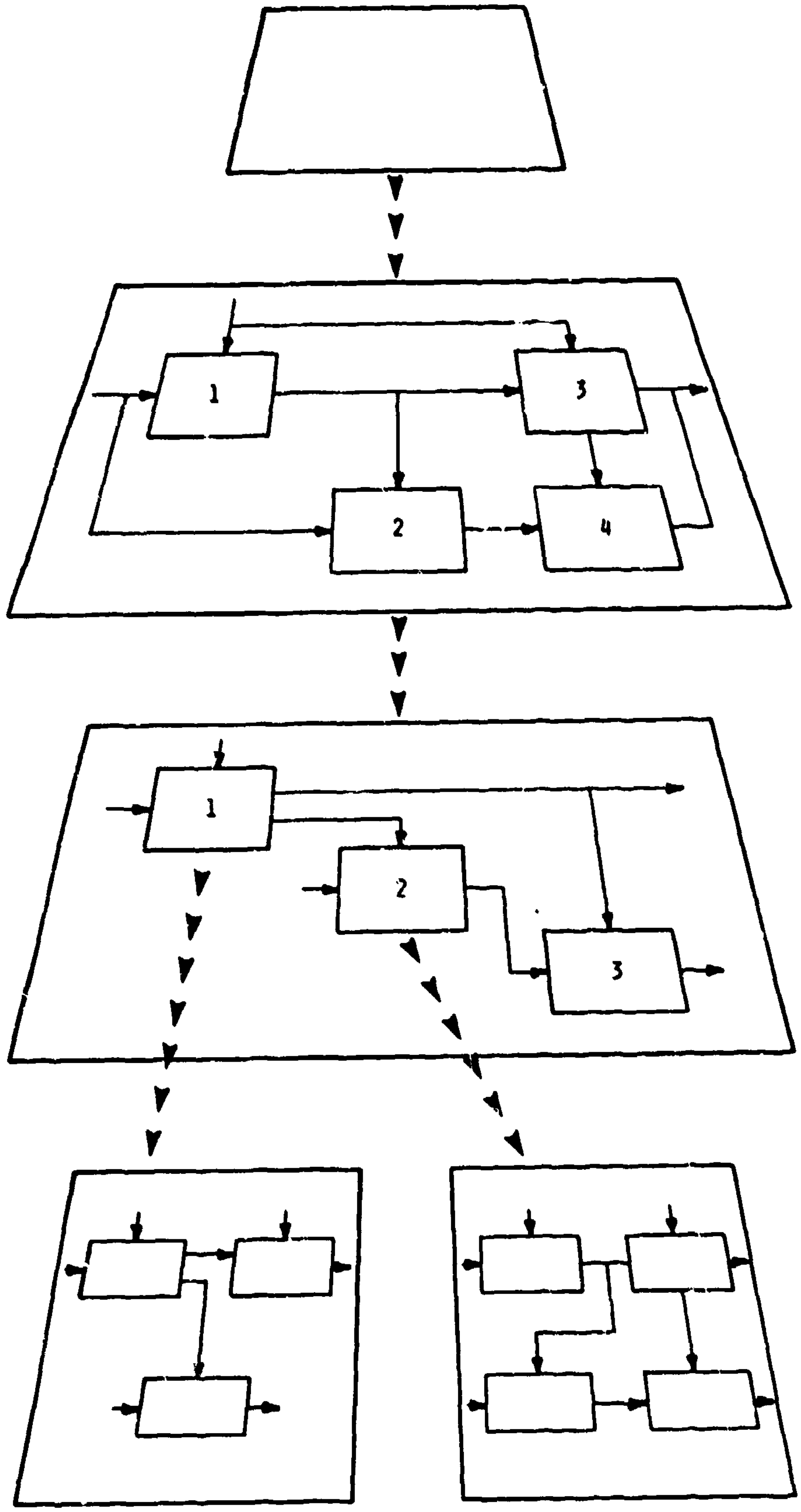

Figure 2-1 Hierarchical Structure of $IDEF_0$ Diagrams

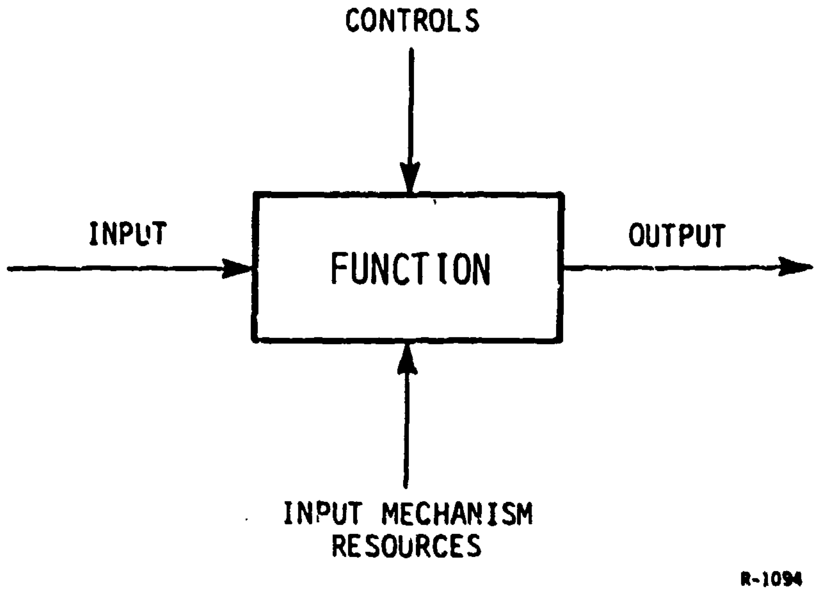

Figure 2-2 IDEF$_0$ Activity Box

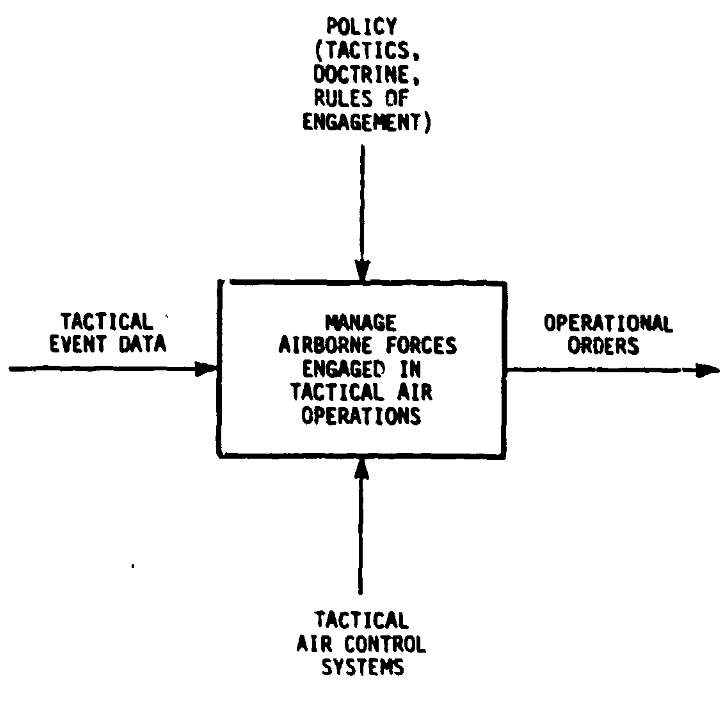

Figure 2-3 Tactical Air Control System: Highest Level IDEF$_0$ Diagram

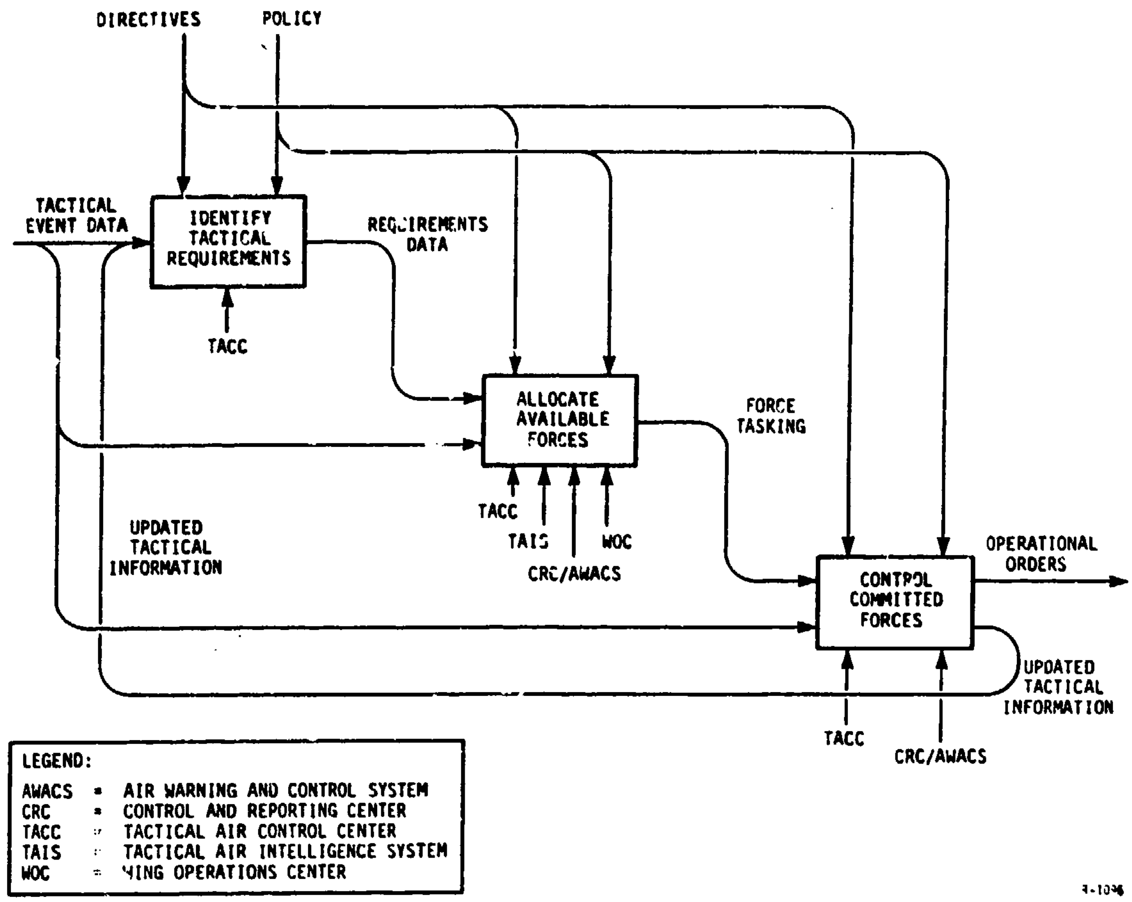

Figure 2-4 Tactical Air Control System: Second Level $IDEF_0$ Diagram

manage the forces engaged in tactical air operations. The highest level outputs of the TACS system are the operational orders.

At the second level in the TAC system (Fig. 2-4), there are three primary activities. They are to identify tactical requirements, to allocate available forces, and to control committed forces. The inputs are the tactical event data, the activity effectors are the Tactical Air Control Center (TACC), Tactical Air Intelligence System (TAIS), Control and Reporting Center and Air Warning and Control System (CRC/AWACS), and the Wing Operations Center (WOC), and the controls are the Air Force directives and policy. The second level outputs are the operational orders and updated tactical information, which

form an input to the identification activity. The outputs of the identification activity are the requirements data which are inputs to the allocation activity. Similarly, the allocation activity outputs the force tasking orders, which are inputs to the control activity. Note that the global inputs and outputs of the second level diagram are identical to those of the first-level diagram, a requirement of $IDEF_0$.

The formality of the $IDEF_0$ procedure requires that the analyst understand the system activities and information flow intimately. As the decomposition descends the hierarchy, the analyst can then begin to address issues such as the criticality of activities and resources, and the effect of policy, doctrine, and constraints in a qualitative fashion.

2.4 RECOMMENDED ADDITIONS TO $IDEF_0$

While $IDEF_0$ diagrams are a useful means of representing system functions and their interaction, they need to be supplemented in order to support quantitative appraisal of C^3I and combat system performance, efficiency, and survivability. In particular, the $IDEF_0$ methodology must be enhanced to represent:

1. Queuing of functions or activities.
2. Data storage.
3. Human decisionmaking.

2.4.1 Queuing

A typical $IDEF_0$ diagram can identify the fact that several functions are performed at a single location or node. In the earlier example of Fig. 2-4, all three functions shown are performed at the TACC. However, it is not clear

from this diagram, nor can it be made clear from further lower-level decomposition, whether the functions are to be performed simultaneously, or in a specified order, or in combinations; or whether they are affected in any way by the information processing capacity of the TACC. Whenever C^3I functions share a location or node, queuing delays and lost opportunities are likely.

Shared nodes can ultimately be decomposed into one or more of four categories:

- Communication link.
- Data processor.
- Memory.
- Human effector or decisionmaker.

It is thus essential to have the capability of representing activity priority, data accessibility in time, and system activity dynamics for quantitative analysis.

2.4.2 Data Storage

The $IDEF_0$ diagram family, as exemplified in Figs. 2-3, and 2-4, are complete in the sense that system functions, data, resources, and controls are represented; yet there is a lack of detail about the nature of the flow of data between functions. $IDEF_0$ implicitly assumes that all data in the system are active, i.e., are constantly being passed from activity to activity without any allusions to memory or storage. This belies reality. Some data are transient, while some are permanently stored for long-term availability.

Figure 2-4 is modified (see Fig. 2-5) to demonstrate data storage. The data "stores" are represented by open rectangles. Note that no direct links remain between the activities, implying that they have been effectively decoupled through the existence of data storage.

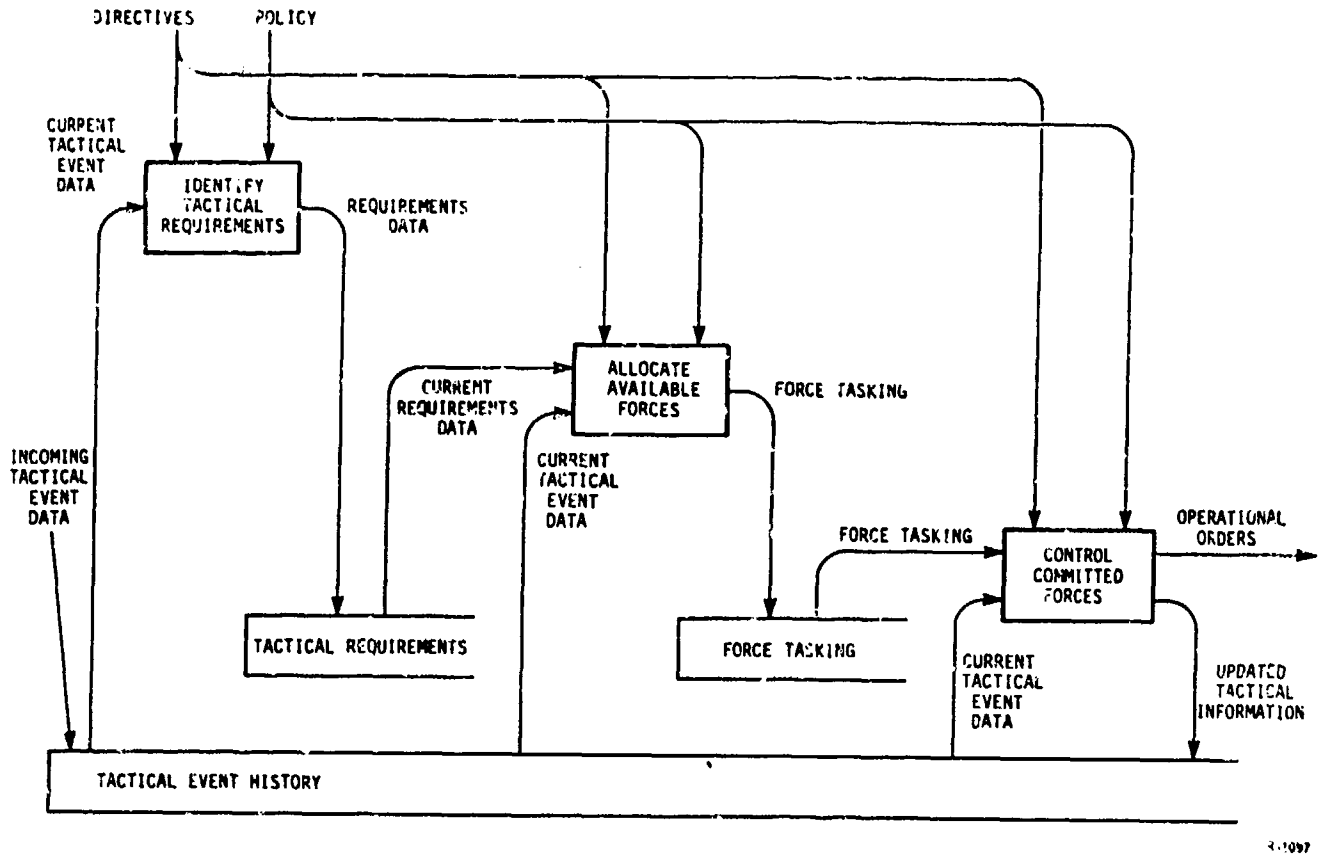

Figure 2-5 Second Level IDEF$_0$ Diagram with Data Storage

The ability to represent data flow in C^{3}I and combat systems serves two other functions:

1. In secure environments requiring compartmentalized information, data store analysis can be considered accessiblity issues.

2. If the data store analysis parallels the IDEF$_0$ analysis, then it will automatically generate a hierarchical data structure.

2.4.3 Human Decisionmaking

In decisionmaking tasks that are not strictly rule-based or proceduralized, it would behoove system analysts to develop a model of the decisionmaker's cognitive process. This model should be capable of encoding the human's information processing and decisionmaking activities. Such a model is

particularly important when the analyst is interested in assessing the role of humans in complex systems.

Typically, human activities are simply modeled as scripts and, when modeled dynamically, as time delays. This approach is suitable for mental functions, but certainly not for consequential tasks. A richer framework for modeling the human decisionmaking process has been recently developed by Wohl [3]. The framework is termed the SHOR paradigm and will be elaborated upon in Section 3.

2.5 MEASURING SYSTEM EFFECTIVENESS

As an analysis tool, $IDEF_0$ itself is incapable of quantitatively measuring system performance. However, it is possible to integrate the static $IDEF_0$ models into a dynamic representation using a simulation language [4]. The simulation will allow the analyst to perform "what if" or sensitivity analyses. Potential variations or innovations in activities, resource availability, data accessibility or quality, and system procedures or doctrine can be assessed in terms of changes in system performance.

The $IDEF_0$ diagrams describe the elements of the system and the characteristics of the elements. If a dynamic description of element interaction over time is developed, as recommended in subsection 2.4.1, then we have the sufficient information to perform a network simulation. The dynamic characteristics comprise the "performance data base."

Development of a performance data base is, however, a nontrivial task. For each activity or function, the following information must be learned.

1. Operational scripts, constraints, priorities, and time to complete.

2. Availability of data and its reliability.

3. Resource precedence requirements and resource reliability measures.

$IDEF_0$ and the SAINT [5] network simulation model have been integrated to analyze C^3 surface-to-air missile (SAM) performance [4]. The model was developed to evaluate tracking error, miss distances, probability of hit, and probability of kill. It was found that the availability of the $IDEF_0$ diagrams pared the usual time and money spend on SAINT development by more than 60 percent.

2.6 DISCUSSION

A brief description of an available technique for large-scale system decomposition has been presented, and an existing methodology that can use an augmented static representation for dynamic simulation to evaluate system performance has been identified. When integrated through the performance data base, the $IDEF_0$ technique and the network simulation model form a parsimonious, coherent methodology for analyzing large-scale man-machine systems.

The utility of using $IDEF_0$ derives from the formality of the procedure. It provides both the analyst and operational personnel a structured framework for describing hierarchical systems. It also provides an efficient format for eliciting the input data needed to construct the performance data base, as evidenced in the SAM application [4]. It should be noted that although all applications to date have used the SAINT network simulation language to measure system effectiveness, any network simulation that has user-definable function capability could be employed.

SECTION 3

MODELING HUMAN COGNITIVE DECISIONMAKING

There exist two distinct approaches to modeling human cognitive decisionmaking. They are termed artificial intelligence and cognitive simulation. The artificial intelligence products are typically employed as decision aids, whereas the cognitive simulation products are used for analysis. To quote Simon [6, p. 496]:

> Artificial intelligence is the discipline that is concerned with programming computers to do clever humanoid things -- but not necessarily in a humanoid way. The closely allied field of cognitive simulation ... is concerned with programming computers to do clever things that people do, but to do them us using the same information processes that people use.

3.1 ARTIFICIAL INTELLIGENCE

The discipline of artificial intelligence is normative in construct. Its goal is to enable machines to perform diagnosis, data interpretation, planning, and design tasks in the stead of humans. Recent efforts in the development of expert systems [7] by artificial intelligence researchers have exhibited a normative-descriptive flavor. An expert system is an artificial intelligence program that uses knowledge and inference procedures to solve complex problems. The knowledge and inference procedures are generally elicited from human experts.

These models, though, have little predictive capability. They rely primarily on analogical reason (diagnosis) since all knowledge (i.e., scripts

or production files) and inference procedures (rule interpreters) are encoded from experts. Their ability to handle uncertainty is often rudimentary.

Expert systems are best applied to problems in which the dominant responsibility is information processing, i.e., mapping stimuli into known situations, hypotheses, or models. There exist successful expert systems for medical diagnosis, scientific data analysis, military threat assessment, and planning and scheduling problems. Two particular applications are discussed below.

The military decison aid, JUDGE - Judged Utility Decision Generator [8], could be construed as an artificial intelligence application under the Simonian interpretation. JUDGE was developed to improve the effectiveness of the Direct Air Support Center (DASC) when the demand for close air support missions exceeds the supply of the strike aircraft. Specifically, the DASC must determine the number of aircraft to commit to a mission request depending upon the value of the target, probability of mission success, number of aircraft available, and forecast of future requests and their respective value distributions.

Two crucial assumptions form the foundation of the model. They are:

1. The DASC can encode target value judgements in real-time.
2. The maximization of expected value is the criterion (Bayes criterion) for decisionmaking.

The solution methodology utilized was finite-horizon stochastic dynamic programming.

The feature of JUDGE that we wish to emphasize is its modification of the role played by human decisionmakers in the DASC. In the conventional scenario, humans evaluate the requests for direct air support and allocate

aircraft sorties. When JUDGE is in use, this scheme is modified in two ways. First, the decisionmaker's role is changed to mission valuation only, and the system carries out the complex calculations needed to do the allocation. Second, the decisionmaker's valuation judgement is aided by the provision of a specific standard relative to which the value of each request is ascertained. The former feature of JUDGE removes the human from a role to which he is ill-suited, i.e., complex forecasting, scheduling, and hedging calculations, and places him in role to which his expertise as a military officer is perfectly suited: evaluating the importance of a particular mission. The second feature, JUDGE's provision of a standard of comparison, was designed to serve as a decision aid, viz., it would reduce the natural tendency of human decisionmakers to vary their assessments of utility in response to irrelevant influences.

Leal [9] constructed a real-time decision aid to configure missile interceptor allocation strategies to protect ICBM silos against enemy reentry missile attacks. This approach represents a major departure from the conventional, nonadaptive ballistic missile defense philosophy. The algorithm overcame the computational complexity usually associated with such problems by using techniques from the disciplines of artificial intelligence and adaptive programming. Specifically, heuristic search and evaluation techniques were employed to pare the decision tree and determine preferred silo defense strategies. The algorithm dispenses with the uncertainty in the enemy's attack pattern by presuming that he knows perfectly the states of nature and seeks to minimize our heuristic evaluation function. We, however, seek to maximize that function.

The state of nature is defined by number of target silos, number of defending interceptors, and the interceptor coverage. The actions are confined to: 1) doing nothing, or 2) defending silo with an interceptor. The algorithm was simulated and performed significantly better than the taper-linear defense strategy developed by the U.S. Army. The magnitude of this improvement is necessarily conservative as the adversary is incorrectly presumed to have perfect knowledge of the states of nature.

Both decision aids have been developed to perform cognitive decision-making tasks for which humans are ill-suited. Both aids perform onerous calculations, thereby liberating the decisionmaker to act on other more worthy tasks.

3.2 COGNITIVE SIMULATION

The discipline of cognitive simulation is descriptive in construct. Its goal is to model human cognitive decisionmaking; not only to produce human-like decisions, but to try and model the human's cognitive processes. These models are generally used to analyze human performance and total man-machine effectiveness.

It has been well-documented that humans are not capable of processing probabalistic data in accordance with Bayes theorem and as such cannot make optimal probabilistic inferences [10; 11; 12]. The prevalent cause seems to be the exiguous size and volatility of a human's short-term memory (STM) [13].

Humans try to overcome this limitation using heuristics or simple models of the world. The notion of humans using simplified models to mitigate their cognitive strain is well-founded in the psychological and human factors literature [14; 15; 16]. Simon [14, p. 198] asserts that the decisionmaker

> ...behaves rationally with respect to this (simplified) model, and such behavior is not even approximately optimal with respect to the real world. To predict his behavior, we must understand the way in which this simplified model is constructed, and its construction will certainly be related to his psychological properties as a perceiving, thinking, and learning animal.

A simple example of a cognitive heuristic is the 7-10, 10-7 doubling rule for compound interest. If the compound interest is 7 percent, then principal doubles itself every ten years, whereas, if the interest is 10 percent, principal doubles itself every seven years. Therefore, one employing this heuristic would determine that an initial principal of $1,000 at 7 percent interest would be worth $32,000 at the end of fifty years, when in reality the true sum would be roughly $29,500.

There are a plethora of other behavioral considerations that are evident and should be accounted for in cognitive simulations of human decisionmaking activities [17; 18]. One application of a cognitive simulation is described below.

A mathematical model of a power system dispatcher's activities under emergency conditions has been recently developed [19]. The objective of the effort is to enhance knowledge of dispatcher behavior and, hopefully, to isolate areas where decision aids and/or decision support might improve his performance. The dispatcher's cognitive processes are conceptualized as a cascading of information processing activity, decisionmaking activity, and forecasting activity. Information processing comprises the initial system state estimation and subsequent updating through transmission line display monitoring. Given the revised state estimates, the dispatcher determines his admissible set of actions, and then evaluates them for decisionmaking. The

criterion for decisionmaking is the minimization of the expected subjective cost associated with any specific status of the power network. The cost is a function of the number and degree of transmission line overloads. After action selection, the operator considers the effects of future failure contingencies and whether or not further actions should be immediately taken to mitigate their respective risks.

Within the information processing, decisionmaking, and forecasting components of the model, human perceptual and cognitive limitations are explicitly incorporated. The limitations include attention allocation, STM, action thresholds, and decisionmaking biases. All model assumptions were either obtained from or corroborated by the dispatchers through structured interviews.

3.3 THE SHOR PARADIGM

Wohl [3] has described a paradigm for the process of human cognitive decisionmaking that conceptualizes the decisionmaking process as four interrelated activities. They are 1) information processing; 2) hypothesis generation and evaluation; 3) option generation and evaluation; and 4) execution. This paradigm has been termed SHOR (stimulus-hypothesis-option-response) by Wohl, who derived the paradigm from classical stimulus-response (S-R) psychology.

SHOR is not an analytical model. It was developed to provide a framework for structuring military decision problems. Decisionmaking tasks often exhibit certain well-defined properties or structures and SHOR provides a generic framework for structuring these problems. Thus, when reference is made to a SHOR model, what is implied is a model that was devised in the SHOR framework.

Table 3-1 depicts the basic elements of the SHOR paradigm in terms of task, input, and output constituents. The table shows that data are sensed and processed by the S or data processing component of SHOR. The H component of SHOR then operates on the processed data (information). The effects of this operation denote the situation or state of the system. The hypotheses, or hypothesis set, generated and under consideration are the result of interaction in the stimulus component between the incoming data and the human's internal representation of the total system. As individuals' expertise increases so will the sharpness and richness of their internal representations of the system. The resulting hypothesis, in any case, provides the basis for comparing the predictions derived from the hypotheses with the incoming data. Incoming data might serve to increase the decisionmaker's subjective confidence in one hypothesis over others also being considered.

Hypotheses are, therefore, generated and evaluated to formulate or to describe the state of the system. Once some conclusion is reached concerning the probable state of the system, the option generation and evaluation or, O, component of SHOR considers the issue of alternative actions and their expected outcomes. Options are considered and evaluated in the light of the current hypotheses and the desired objectives. It is assumed that decisionmakers attempt to make optimal decisions, but because of inherent cognitive limitations and situational constraints, they satisfice. (Satisfying connotes operating suboptimally but doing the best one can in the situation.)

Lastly, one action or response, R, is organized and executed in line with the option selected and, in turn, creates one observable effect on the states of nature. This effect may or may not be veridical with the decisionmaker's expectations, depending upon the validity of his internal model.

TABLE 3-1 SHOR PARADIGM IN TERMS OF TASK ELEMENTS

	S	H	O	R
	STIMULUS	HYPOTHESIS	OPTIONS	RESPONSE
TASK	PROCESS DATA	MAP DATA INTO INFORMATION	EVALUATE ADMISSIBLE ACTIONS	EXECUTE ACTIONS
INPUT	ENVIRONMENTAL DATA	SENSORY DATA	HYPOTHESES ABOUT STATE OF NATURE	DECISIONS THAT AFFECT STATES
OUTPUT	SENSORY DATA	HYPOTHESES ABOUT STATE OF NATURE	DECISIONS THAT AFFECT STATES	RESPONSES

R-1048

3.4 SHOR AND COMBAT SYSTEM ANALYSIS

SHOR is a framework for modeling human decisionmaking activity. Thus, every activity block in an IDEF$_0$ diagram that deals with a human can be modeled within the SHOR framework. With such a model, and the requisite performance data base, a network sumulation of the combat system can be performed and quantitative measures of effectiveness derived. Note that a similar procedure is possible with artificial intelligence applications. The exercise is best conveyed through an example.

Antisubmarine warfare. In an analysis of a Naval carrier group, one of its activities is to evaluate the antisubmarine warfare (ASW) threat. The IDEF$_0$ activity diagram is depicted in Fig. 3-1. The inputs are the sensor

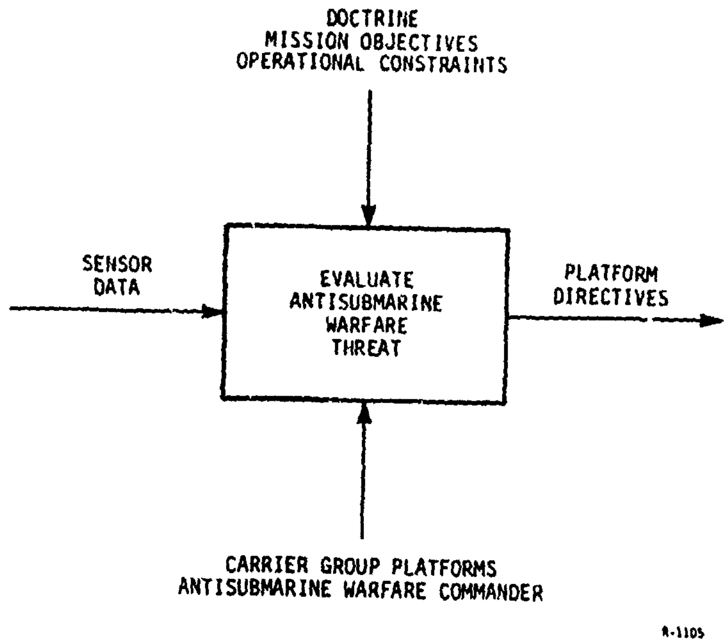

Figure 3-1 Antisubmarine Warfare Threat Activity Diagram

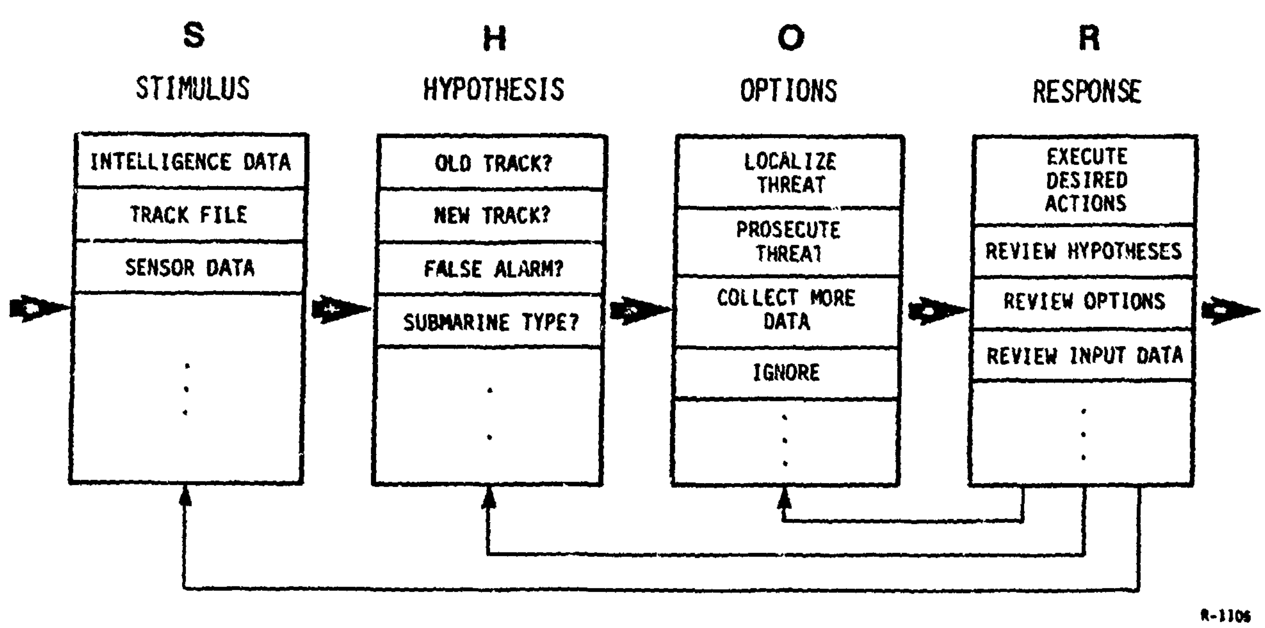

Figure 3-2 SHOR Decomposition of Antisubmarine Warfare Threat Activity

data. The controls are the Naval doctrine, mission objectives, and operational constraints. The carrier group platforms are the resources, and the activity is carried out by the antisubmarine warfare commander (ASWC). The outputs are the platform directives, i.e., orders to change course, launch a helicopter or a fixed-wing aircraft to place sonobuoys for further localization, or to prosecute a localized threat.

An example of how SHOR can be used to structure the cognitive decision process of an ASWC is shown in Fig. 3-2. Given this structure, cognitive models of how the hypotheses and options are generated, and how hypotheses and options are evaluated must be constructed.

Depending on the depth of the modeling effort, the effects of different personnel, perturbations in data reliability, and resource (asset) constraints could potentially be appraised in a simulation. Herein lies the utility of cognitive simulations. If individual decisionmaking attitudes can be represented, then commander training weaknesses can be brought to bear, furthermore, the model could be used to evaluate candidates and the cost effectiveness of new hardware and software innovations could also be assessed.

SECTION 4

CONCLUDING REMARKS

The high complexity and connectivity associated with future distributed C^3 systems will render their analysis significantly more difficult than that of traditional centralized systems. Recognition of this fact has motivated the search for a unified approach to C^3 system analysis. This report has suggested the use of a particular static functional decomposition methodology, $IDEF_0$, as the first element of such an approach. Several augmentations to the present $IDEF_0$ approach were suggested to better deal with particular facets of C^3 systems, particularly the use of the SHOR paradigm to represent human decisionmaking. In addition, a technique for measuring C^3 system effectiveness via $IDEF_0$ and a network simulation model, such as SAINT, was discussed.

REFERENCES

1. "Distributed Decision Making Environment," ALPHATECH, Inc., TP-146, Burlington, Massachusetts, 1981.

2. Colter, M.A., R.A. Miller, and J. G. Wohl, "Integrated Analysis Techniques for C^3 Systems," System Development Corporation, Technical Report, Colorado Springs, Colorado, 1982.

3. Wohl, J.G., "Force Management Decision Requirements for Air Force Tactical Command and Control," IEEE* Transactions on Systems, Man, and Cybernetics, Volume SMC-11, Number 9, September 1981, pp. 618-639.

4. Bachert, R.F., K.H., Evers, C.M., Hoyland, and E. Rolek, "Static and Dynamic Model Integration for a SAM C^3 Simulation via $IDEF_0$/SAINT," Proceedings, IEEE International Conference on Cybernetics and Society, October 1982.

5. Siefert, O.J., and G.P. Chubb, "SAINT: A Combined Simulation Language for Modeling Large Complex Systems," Aerospace Medical Research Laboratory, AMRL-TR-78-48, Wright-Patterson Air Force Base, Ohio, 1978.

6. Simon, H.A., "On How to Decide What to Do," Bell Journal of Ecomonics, Volume 10, 1978, pp. 494-507.

7. Gevarter, W.B., "An Overview of Expert Systems," Department of Commerce, National Bureau of Standards, NBSIR 82-2505, Washington, D.C., May 1982.

8. Miller, L.W., R.J. Kaplan, and W. Edwards, "JUDGE: A Value-Judgement-Based Tactical Command System," The RAND Corporation, RM-5147-PR, Santa Monica, California, 1967.

9. Leal, A., "Adaptive Decisions in Ballistic Missile Defense," IEEE Transactions on Systems, Man, and Cybernetics, Volume SMC-7, Number 5, May 1977, pp. 398-402.

10. Kahneman, D. and A. Tversky, "On the Psychology of Prediction," Psychological Review, Volume 80, 1973, pp. 293-326.

*IEEE - The Institute of Electrical and Electronics Engineers, Inc.

REFERENCES (Continued)

11. Lopes, L.L., "Averaging Rules and Adjustment Processes: The Role of Averaging in Inference," Office of Naval Research, NR 197-068, Arlington, Virginia, 1981.

12. Slovic, P., "Toward Understanding and Improving Decisions." In Howell, W.C. and E. A. Fleishman, (Eds.), Human Performance and Productivity: Vol. 2, Information Processing and Decision Making, Erlbaum Associates, Hillsdale, New Jersey, 1982.

13. Miller, G.A., "The Magical Number Seven, Plus or Minus Two," Psychological Review, Volume 63, Number 2, 1956, pp. 81-97.

14. Simon, H.A., Models of Man: Social and Rational, John Wiley and Sons, Inc., New York, 1957.

15. Veedhuyzen, W. and H.G. Stassen, "The Internal Model: What Does it Mean in Human Control." In Sheridan, T.B. and G. Johnson (Eds.), Monitoring Behavior and Supervisory Control, Plenum Press, Inc., New York, 1976.

16. Jagacinski, R.J. and R.A. Miller, "Describing the Human Operator's Model of a Dynamic System," Human Factors, Volume 20, Number 4, 1978, pp. 425-433.

17. Janis, I.L. and L. Mann, Decision Making, Free Press, Inc., New York, 1977.

18. Sage, A.P., "Behavioral and Organizational Considerations in the Design of Information Systems and Processes for Planning and Decision Support," IEEE Transactions on Systems, Man, and Cybernetics, Volume SMC-11, Number 9, September 1981, pp. 640-678.

19. Pattipati, K.R., E.E. Entin, S.W. Gully, and D.L. Kleinman, "A Normative-Descriptive Model of a Power System Dispatcher in Emergency Situations," Proceedings, American Control Conference, Arlington, Virginia, June 1982, pp. 283-291.